ISSN 1063-7710, Acoustical Physics, 2009, Vol. 55, No. 3, pp. 448–450. © Pleiades Publishing, Ltd., 2009.

ACOUSTICS OF ANIMATE SYSTEMS. BIOACOUSTICS

Perception of the Sound Source Position[1]

Larisa Dunai, Guillermo Peris Fajarnes, Beatriz Defez Garcia, Nuria Ortigosa Araque, and Fernando Brusola Simon

Universidad Politecnica de Valencia, Research Center in Graphic Technology, Camino de Vera s/n, Building 8L, 46022 Valencia, Spain

e-mail: ladu@upv.es

Received September 25, 2008

Abstract—This paper presents several experiments on sound source localization. They are based on monaural click presented at different interclick intervals (ICI), from 10 to 100 ms. Trains of clicks were presented to 10 healthy subjects. At short interclick intervals the clicks were perceived as a blur of clicks having a buzzy quality. Moreover, it was proven that the accurateness in the response improves with the increase of the length of ICI. The present results imply the usefulness of the interclick interval in estimating the perceptual accuracy. An important benefit of this task is that this enables a careful examination of the sound source perception threshold. This allows detecting, localizing and dividing with a high accuracy the sounds in the environment.

PACS number: 43.66.Qp

DOI: 10.1134/S1063771009030233

Sound source localization is an important function for humans [1, 2]. Two main factors of binaural cues such as interaural time and intensity difference facilitate the sound source localization in the horizontal plane [3, 4] According to the duplex theory, these two factors provide the main information about lateral position of the sound source [5]. However, in conditions involving multiple brief sounds and far distances, the precision of the sound localization is reduced [6], the subjects mislocalize the sounds, perceiving them as traveling from one position to another.

In the present study, the performances of the auditory localization task across a broad range of interclick intervals ICIs were examined, reaching the conclusion that the correct response increases when the length of the ICIs increase.

Two factors were varied: the interclick intervals (ICIs) (10, 12, 25, 50 and 100 ms) and the sound complexity.

A click of 5 ms duration with Above Audition has been generated. Figure 1 is a picture of the considered click. The *x* axis represents the time scale in seconds and the signal speed of 29.97 fps. In order to achieve the objective of the proposed study, two experiments have been carried out. In the first case, the generated click with duration of 5 ms has been used as spatial sound and in the second case, the click has been multiplied by six, forming a train of clicks with a duration of 30 ms.

[1] The text was submitted by the authors in English.

The click has been spatialized by using Head Related Transfer Function (HRTF). It is known that the HRTF is very important for sound localization, because it expresses the sound pressure at the listeners eardrum over the whole frequency range (see Fig. 2). In the present study, the HRTFs were generated at 80dB at a frequency of 44100 Hz and processed by a computer for the frontal plane for the distance of 2 m with azimuth of 64° (32° at the left side of the user and 32° at the right side of the user).

In the experiments the spatial click were presented randomly in pairs Left-Right and Right-Left, delivered using Matlab version 7.0, on an Acer laptop computer. Figure 2 shows the schematic presentation of the sound: (a) shows the monaural click in which, the click come from L ⟶ R and R ⟶ L randomly varying ICIs; (b) shows the train of clicks, where the presentation procedure is the same as for the single

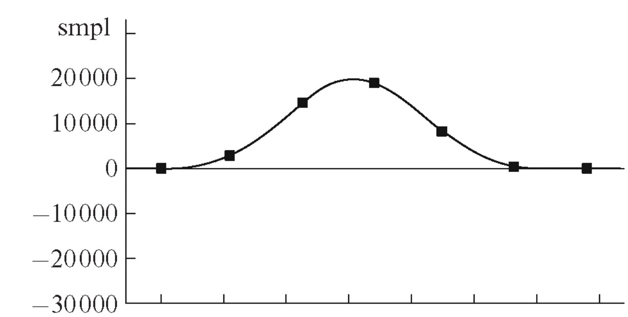

Fig. 1. Click wave form.

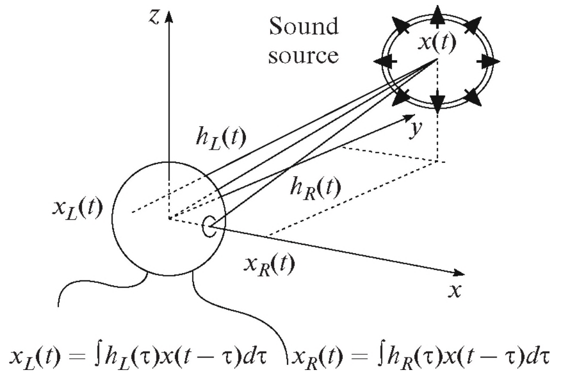

Fig. 2. HRTF coordinates presentation, where the $h_L(t)$ and $h_R(t)$ represent, respectively, the Lead-related impulse response HRIR at the eardrum for the sound source $x(t)$ at each ear, left $x_L(t)$ and right $x_R(t)$. The $x_L(t)$ and $x_R(t)$ could be calculated using the convolution integral $x_L(t) = \int h_L(\tau)x(t-\tau)d\tau$ and $x_R(t) = \int h_R(\tau)x(t-\tau)d\tau$, where τ is the delay.

click, the sound come from L ⟶ R and R ⟶ L randomly varying ICIs. In both cases the experiment begins with various exercises where the subjects are able to listen the clicks and train of clicks by separately the left one after that the right one, the combination L ⟶ R and R ⟶ L. In this experiment participate ten non-paid volunteers, 4 females and 6 males, age range 27–40 years, average 33.5, all with PhD students and professors. Each subject reported to have normal hearing. All of them were supposed to other acoustical experiments with computer and acoustical mobility devices. The subjects were supposed to listen through headphones, HD 201 model, twelve pairs of sounds, six pairs of single clicks and six pairs of trains of clicks Left-Right and Right-Left at different ICIs from 100 to 10 ms in a decreasing succession. Between each two consecutive pair of clicks, the decision time Td was computed; this was the time needed for evaluating the sound (see Fig. 3). The subjects were asked what they listened, the number and the provenience of the listened sound and also if there was any difference between them. The subjects where allowed to repeat them, if necessary, after they had evaluated the perceived position for each click with Left, Right and possible Centre. Once the subject had selected a response, a next pair of clicks was presented. Each trial lasted approximately 2 min. The average time per subject was around 35 min.

Besides, there were some distraction cues as: environmental noises, draw away seeing or listening someone, since the subject remained with opened eyes. Because of this reason, the subjects were allowed to make judgements about the source location independently.

The main response of the data for all subjects is presented in Fig. 4. The perception of the single and train of clicks and the perceived position of the sound pairs Left-Right and Right-Left were analyzed. Both factors as well as were the interaction with the ICIs were significant.

Figure 4 shows that the perception of the sound source position decreases when ICIs does. For avoiding errors the tests results were registered up to an ICI of 10 ms. Because ICI was enough short, the clicks were perceived as a single entity moving from one ear to another or from one ear to the centre having a buzzing quality.

In the case of the single pair of clicks at ICI of 12 ms, because the length of the clicks and the length of the ICI were too short, the subjects could not distinguish clearly the clicks corresponding to the pairs Left-Right and Right-Left.

When comparing the perception of the single clicks with the perception of the train of clicks a great continuity of the sound position across almost the entire range of ICIs was detected. In other words, the perception of the sound position was stronger for the train of clicks and extended to short ICIs (100–10 ms). This effect may be a result of the better localization associated with the sound. In

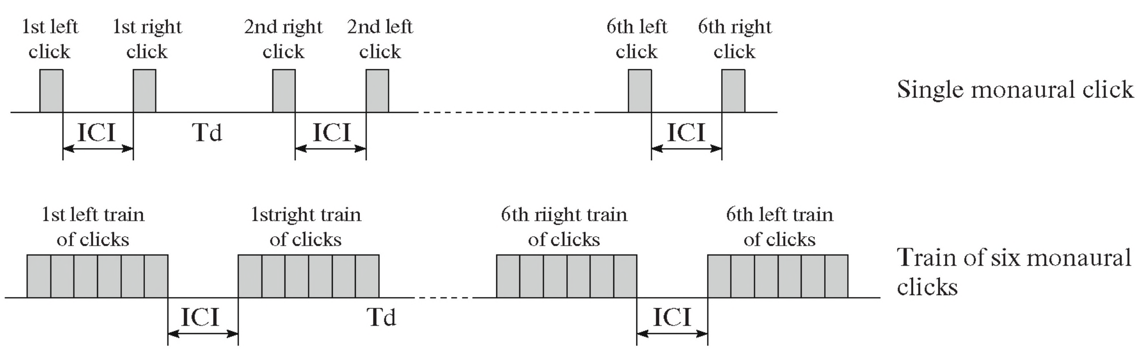

Fig. 3. Schematic presentation of the sound. In both situations the click is of 5 ms. In the first case, the click has been listened at different interclick intervals ICI separated by a decision time Td. In the second case, the click has been substituted by a train of six clicks.

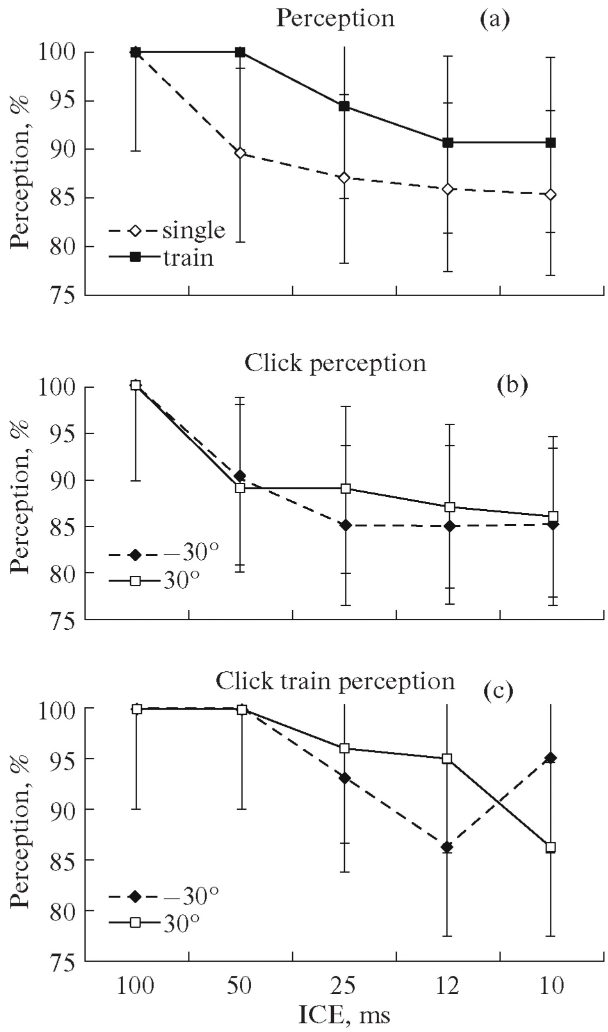

Fig. 4. Mean estimation of the click location. (a) Represents the perception of the single click and the perception of the train of clicks at 0° (center) at different ICIs; (b) shows the click perception at −30° (left side) and +30° (right side); (c) corresponds to the train of click perception at −30° (left side) and +30° (right side).

general, these sounds would be perceived from other sound.

For ICIs of 25 to 10 ms, the subjects perceive the Right-Left pair of sounds with a higher precision than that of pairs Left-Right for single click and train of clicks.

In other case, for ICIs of 50 ms, the perception of the pair of single clicks Right-Left is higher than the perception of the pair Left-Right. In the case of the train of clicks, the perception results are equivalent for both pairs Left-Right and Right-Left.

CONCLUSION

When trying to explain the sound source perception threshold, we perceive the perception of the saltation illusion. With short ICIs a blur of clicks were perceived, in contrast with the individual clicks at longer ICIs. As the psychologist Gestalt noted, the perceptual system scrambles for the simplest interpretation of the complex stimuli presented in the real world. Therefore, the studies were based on analyzing and proving that, grouping the clicks, the sound source is better perceived and localized. For longer ICIs, this procedure is not too much important, as each click can be identified and localized.

The present results demonstrate the usefulness of the interclick interval in estimating the perceptual accuracy. A possible benefit of this task is enabling a careful examination of the sound source perception threshold. This allows detecting, localizing and dividing with a high accuracy the sounds in the environment.

ACKNOWLEDGMENTS

This work was financially supported by the European Commission through CASBliP project, FP6-2004-IST-4. We would like also to thank A.R. Hernandez from Universidad de la Laguna, Spain for HRTFs collection.

REFERENCES

1. R. Hari, Neurosci. Lett. **189**, 29 (1995)
2. S. B. Douglas and W. R. Raibiowitz, J. Acoust. Soc. Am. **106**, 1465 (1999).
3. J. C. Kidd and J. H. Hogben, J. Acoust. Soc. Am. **116**, 1116 (2004).
4. G. G. Harris, J. Acoust. Soc. Am. **32**, 685 (1960).
5. S. B. Douglas, I. Nathaniel, and W. R. Raibiowitz, J. Acoust. Soc. Am. **106**, 1956 (1999).
6. B. H. Deatherage and I. J. Hirsh, J. Acoust. Soc. Am. **31**, 486 (1959).